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ABSTRACT

The role of content in formal operations tasks was explored in research that systematically varied the content of tasks and children's performance by developmental level and socioeconomic status (SES). Subjects were 110 Icelandic 12-year-olds who had entered a longitudinal study when they were 7 years old. Two extreme ability groups of children from Reykjavik primary schools were formed. Measures of formal operations employed were two tasks of variable isolation and measures of conservation of displacement volume. Variable isolation tasks were the pendulum problem and three content versions of the plant problem. Subjects were asked to isolate the operative variable and exclude the inoperative ones. Displacement of volume tasks were of two kinds: a formal Piagetian version and another version judged to be more experiential or familiar to subjects. Each content version was tested by means of three different forms of tasks, in which the shape or weight of the inserted object or the size of the container was varied. The experimental version involved a set of cartoon stories of social games. Three variations, which were similar to variations of the formal tasks, were presented. All tasks were administered, along with classification tasks and syllogisms, in a school setting in one session. Findings indicated that while formal operational thought differed by SES and gender, Piagetian tasks were biased for SES only. (RH)

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Role of content for the performance of 12-year-olds by gender, SES and developmental level on formal operational tasks

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The paper is partly based on the author's Ph. D dissertation from the University of Leeds. The data was collected as part of a larger research project "*Child Development and Social Structure* " whose principal investigator is Wolfgang Edelstein, Max Planck Institute of Human Development and Education, West Berlin.

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One of the hallmarks of formal operational thougt according to Inhelder and Piaget (1958) was the capacity to dissociate completely form from contents . Later Piaget revised this view of the role of content in formal operations and favored the hypothesis that the stage of formal operations can be reached in different areas according to aptitudes or professional specializations (Piaget,1972:205-207). This position of Piaget fits findings that suggest that certain groups like adults (Sinnott,1975), girls (Peskin,1980) or Kalahari bushmen (Tulkin and Konner 1973) perform better on some formal operational tasks than others . Tasks that have "familiar" or "interesting" content seem to be easier than the more formal or "scientific" tasks. This fact is generally acknowledged in later performance theories and it can be argued that this point is no longer problematic for Piaget's theory as long as evidence of some structural thresholds appears. It can also be argued, however, that this still is a problem for a competence theory like Piaget's (see Moshman and Neimark, 1982) in view of the fact that the traditional tasks of Inhelder and Piaget are often used as the sole measures of formal operations regardless of age, interests, gender, SES or cultural background (see Meehan 1984 for a review of studies).

In constructing a fair task of formal operations one runs into difficulties related to the disentangling of competence from performance factors (See Glick1975, Neimark1979, Stone and Day 1980, Overton and Newman 1982). It seems clear that individual or group difference factors interact with task variables in complex ways, which deserve further exploration.

In view of criticism of a bias of the formal operational construct due to emphasis on form and disregard for content and experience and an overemphasis on scientism (Gilligan and Murphy 1979, Buck-Morss 1975, Donaldson 1978, Broughton, 1984) the role of content was one of the foci of a larger study of cognitive development by ability, gender and SES in Iceland.

The major questions of this paper are:

1) Is there a systematic relationship between content variations on tasks of formal operations and performance by gender, SES and ability level among 12- year- old children?

2) Do the findings lend support to the view that the formal operational construct or particular aspects or measures of it are gender or SES biased?

Method

The subjects were 110 Icelandic 12 - year-olds who had participated in a longitudinal study since age seven and did up to age 15. Two extreme ability groups of children from all Reykjavík primary schools were formed. Half of each ability group was males and half females and in each group children came from all social backgrounds, more specificly the two ability groups were matched by SES.

The measures of formal operations used were: Firstly, two tasks of variable isolation i.e. the Pendulum problem adapted from Inhelder and Piaget (1958) and three content versions of the plant problem adapted from Kuhn and Brannock (1977) (see figure 1) . The plant problem was constructed such that one variable (plant food) was operative in influencing the plant's health, and the other two variables were ineffective. The subject's task is to isolate the operative variable and exclude the inoperative ones, parallel to that in the pendulum problem.

Whereas the plant problem was considered to be a "natural" task for all the children, the content of the toy version was thought to be closer to their actual experience. (see figure 2). Purposely that task was constructed in a way that makes it unlikely that it can be solved correctly by experience alone, i.e. the operative variable is not the one that in reality is most likely to be operative for this sample of children. In the third content version (house painting, see fig.3), the same number of operative and inoperative variables are used, but in a more abstract form (materials A, B, X, etc.). The content of this third task was purposely chosen as a "traditional male

activity" as it was considered possible that the plant item would be more interesting or meaningful for girls than boys.

The second set of tasks used were measures of conservation of displacement volume. Although such measures are sometimes discussed in relation to other conservation tasks and the concrete operational stage, they are generally classified as belonging to the formal-operational stage, the proportionality scheme (see Inhelder and Piaget 1958:20, 36 and Meehan, 1984:1111).

Two different content versions were used; a formal Piagetian version and another version judged to be more experiential or familiar for the children. Each content version was tested by means of three different forms of tasks, i.e. either the shape of the object inserted into a container was changed, or its weight or the size of the container itself.

The formal version consisted of two high and thin glasses half filled with water. Either reformed clay (Ball-->sausage) or black-painted tubes identical in shape and size but different in weight were levered into the glasses. Thirdly two glasses of unequal size completely filled with water were used and the question posed was if the same or different amount would be spilled from the glasses if two identical balls were put into them.

The experiential version consisted of a set of cartoon stories of social games presented on pictures and no manipulation was requested. (see figure 4). As with the formal tasks three variations were presented, i.e. either the shape or the weight of the inserted object, or the size of the container was manipulated.

Procedure

All the tasks were administered in a school setting in one session along with other cognitive measures i.e. classification tasks and syllogisms. Each child was tested individually by one of three females. The order of presentation was such that the formal versions were presented after the more experential versions of the tasks.

Results

When the performance on the different variable isolation tasks is analysed by ability level the results are as follows: (Show Table 1).

On the pendulum problem 7% of the low ability group and 34% of the high ability one performed at the formal level. Corresponding percentages for the other tasks are very similar at its best: the percentages range from 7-9 % on the different content versions among the low ability group and from 13 to 32% among the high ability group.

Inspection of Table 1 shows furthermore that of those who reach formal operations the fluctuation of scores on the tasks is much greater among the high ability group than the low ability one. The trend is reversed at the other end which suggests that the low ability 12-year-olds are mostly moving from the concrete to the transitional level, and the high ability children from the transitional to the formal level .

It can also be seen on Table 1 that the toys task, whose content was considered most meaningful for the sample, with the snag that the correct answer was not likely in reality, turned out to be easiest among the high ability group (32% at formal level), and most difficult among the low ability one (64% at the concrete level).

No gender differences appeared on any of the isolation of variables tasks.

As shown on Table 2 however a considerable SES difference was observed on the pendulum among the high ability group. Of the 34% who performed at the formal level (acc. to Table 1) 19% were from the lower SES groups and 48% from the higher ones. If this is analysed more quantitatively in terms of means it yields a significant t score ($t=2.34$, $P< .03$) and an anova yields a significant main effect for SES ($F(1,52) = 5.249$, $P< .03$). No SES differences were observed on the other tasks of variable isolation, nor among the low ability group.

On the conservation of volume tasks the performance of the low ability group was better on the more "experential" or cartoon tasks than the formal tasks and significantly so on the explanation variable.(Table 3)
The reverse is true for the high ability group (see positive ts), although the difference does not reach statistical significance.

Gender differences however (see Table 4), although minor among the low ability group, were significant on six out of 10 composite variables among the high ability one. The gender differences occur both on the cartoon tasks and the formal scientific tasks, on both variables where weight is the distractor and more frequently on explanation than answer variables.In terms of effect sizes the m.d. range from .63 to .78 indicating that the means on those variables are that much of a standard deviation apart. An anova analysis yielded a significant main effect for gender both on the formal composite score ($p<.02$) and the equivalent cartoon score ($p<.03$).

Minor SES differences appeared on the volume conservation tasks among both the high and the low ability groups, when analysed in terms of individual variables presented in Table 4 . A significant SES difference appeared on one variable only for both groups (i.e shape distracts a combined answer score for both content versions). An analysis of variance however showed a significant main effect for SES on the combined formal score but not on the equivalent cartoon score.

Conclusions and Discussion

The questions raised about the validity of Piaget's theory in this paper concern the relationship between form and content of formal operational measures and performance by ability, SES and gender. Although the data are generally consistent with Piaget's revised theory of formal operations (1972) no evidence of falsification was found which according to Popper (1972) would have said more about the theory.

The observed relationship between content variations on the volume tasks and ability level were as could be expected from Piaget's theory . The low ability group performed better on the cartoon version than the formal one, but the difference was

nonsignificant for the high ability group. This might indicate that the cognitive structures of the low ability group are less consolidated and less stable than those of the other group and under those circumstances the less formal or less disembedded (Donaldson 1978) cartoon task content makes a difference.

On the variable isolation tasks the performance of both ability groups was very similar on the pendulum on the one hand and the easiest versions of the other tasks on the other. This corresponds to the findings of Kuhn and Brannock (1977) and Neimark (1975). The finding that the fluctuation in performance on the three content versions of the "plant " tasks was at the upper end for the high ability group and at the lower end for the other group, suggests a move from the transitional to the formal and from the concrete to the transitional for the two ability groups respectively. If the three content versions (i.e. plant, house and toys) are considered from the point of view of familiarity or meaningfulness the toys version would probably be rated first. The results from the other tasks also suggest that the more familiar the content the better the performance, with one exception: the results from the toys version suggest that familiar content is not necessarily beneficial,can even be a hindrance to performance, if logical capacity is not adequate. The most likely explanation is that the low ability group was distracted by the familiar content, i.e. the logically correct answer (a pen) was for them far from being the favorite toy in reality. This indicates that experience can replace thinking or interfere with the inference as so vividly shown, for example by Luria (1976). This did not seem to happen among those who had reached formal operations, in support of a structural theory.

Among the high ability group there was a significant SES difference on the pendulum, which did not appear on the other variable isolation tasks. On the volume tasks minor SES differences appeared among both ability groups which showed as a significant main effect on the formal version, not the cartoon version, i.e. by changing the content of the tasks SES differences disappear. This suggests that these particular Piagetian tasks rather than the formal operational construct they are designed to measure are SES biased. In other words the SES differences appeared on the

performance on these particular tasks rather than on the competence for thinking formally (see Buck-Morss 1975). The author feels justified in using the term "bias" as these tasks were the only ones that yielded significant SES differences of a larger battery of tasks and these differences were not reflected in school achievement at age 12, nor later at age 13 or 15 and minimally if at all at age 14 (SES differences appeared on 2 marks out of 17 among the high developers of the sample only).

What about the observed gender differences? Three recent meta-analyses of gender differences in cognition suggest that the average proportion of variance in cognition explained by gender ranges from .01 to .05 and that the effect sizes are greatest on specific types of spatial ability and on proportional reasoning tasks, in favor of males. On statistical grounds , larger differences can be expected in extreme ability groups (Hyde, 1981). The Piagetian task of of conservation of volume can be classified as a proportional reasoning task (see Meehan, 1984) and gender differences are generally reported on tasks of displacement volume(see Elkind,1961, Shayer and Wylam, 1978, Meehan 1984, Guðbjörnsdóttir 1987). In view of this and Piaget's (1972) hypothesis that the content of the tasks matter, two different content versions were used one of which did not require physical manipulation (See Lawson, 1975) , with limited effects on the observed gender differences. The effect sizes ranged from .61 to .78 which is medium to large (Cohen, 1969). Why the items where "weight" was the distractor yielded more gender differences than the other items, and why the explanation variables were more difficult for females than the answer ones might be just because they are more difficult or a later achievement generally. Another possibility of explaining the difficulty girls had with the explanations are findings that suggest that girls are more reluctant and insecure in explaining scientific phenomena(See Linn, De Benedicts et. al 1987), which is noteworthy in view of the findings accumulating in the literature that show that girls interact less with teachers than boys and therefor get less feedback on their knowledge or understanding and less practice in justifying their answers.

In spite of this change of content both versions of the displacement volume tasks concern physical laws, and can be classified as scientific like most Piagetian measures of formal operational thought. This reflects Piaget's scientism , for which he has been criticised for example by Buck-Morss(1975) and Broughton(1984). The latter accuses Piaget of reducing the theory of knowledge to the philosophy of science without grounding the assumtion that that knowledge can be identified with its scientific branch. From a feminist viewpoint , and the fact that the sphere of science has very much been male dominated(see Howe 1982 and Gilligan 1982) it is important to find out if the scientism of these Piagetian tasks is what makes them gender biased or if it is the formal operational construct itself or aspects thereof. Although Piaget's scientism is but one of many shortcomings of his theory (see Broughton 1984, Vuyk 1981) it is of great concern if its developmental endpoint or the tasks generally used to measure it are gender fair or not.

The fact that no gender differences emerge on the isolation of variables in this study or generally (see Meehan 1984) suggests that it is not the formal operational construct in general but the specific phenomenon of displacement volume or proportinal reasoning that is not gender fair. Whether or not this can best be explained by "scientism" or by relating these tasks to spatial ability, it is clear that in this study no gender differences were observed in science achievement in school at age 12, nor later i.e. at 13, 14 or 15 in the sample concerned. In view of this and the fact that at age 9 the same thing happened when dolls in bathtubs were used instead of the cartoon version it is concluded that the displacement volume tasks regardless of content are gender biased and they are not recommended as general measures of cognition.

It is of urgent importance in the authors opinion to investigate further the observed SES and gender related differences in formal operational thought and discover if this is a task or other "utilization" phenomenon (Overton and Newman,1982, Meehan 1984) and possibly consistant with Piaget's revised theory. Alternatively if the developmental endpoint of Piaget's theory is biased towards the

thought of the "western scientist" at the expence of other forms of cognitive behavior (see Moshman and Neimark 1982). In either case it is of interest to analyse further the relationship between such SES and gender related differences and achievement both in school and in other spheres of society. If no such relationship can be found their validity as cognitive measures is questioned and their use is not justified as a general measure of cognition.

Alternatively when task content does influence the performance of certain groups on structural measures as those of the Piagetian kind, as was the case with the different ability and SES group groups on the tasks used here, it is necessary to bear this in mind in group comparisons, both when tasks are selected and results interpretated.

My conclusion regarding a systematic effect of varying the content of tasks and performance by developmental level and SES is consistent with Overton et. al. 1987 that both the nature of logical competence and task content affect solutions:

1) Content variations and performance by ability on the volume task suggest a facilitative effect of familiar or meaningful content, for the low developers. The results from the variable isolation task suggest that the pendulum is as easy as the easiest version of the other tasks, which is not surprising in view of Kuhn and Brannock (1977) and Neimark (1975). The results from the other tasks suggest however that the more familiar the content the better the performance among the high ability group. Among the low ability group, most of which were not performing at the formal level, content variations influenced performance along similar lines, with one exception: the results from the toys version suggest that familiar content can be a hindrance, if logical capacity is not adequate. This indicates that experience can replace thinking or interfere with the inference if the subjects are below the formal operational level. This did not seem to happen among those at the formal level, which supports a structural theory.

2) Content variations and performance by children of similar ability but from different SES groups suggest that the differences that appear on the formal tasks are

not due to differences in logical capacity but to differences in experience or world knowledge, as the SES differences disappear both on the volume and the variable isolation tasks when more familiar task content is used. This difference does not seem to matter for school achievement in Iceland up to three years later. This suggests that these formal Piagetian tasks are SES biased that can be related to the content of the tasks rather than to a difference in structure or the logical ability they are designed to measure.

3) Content variations and performance by gender did not matter on the variable isolation tasks, were no gender differences appeared. On the conservation of volume tasks however, a strong gender difference was observed particularly among the high ability group, which did not change by making the content of the tasks more familiar and non-manipulative. This gender difference does not seem to affect school performance up to three years later, was specific to the volume tasks out of a larger battery of tasks (See Gudbjornsdottir 1987, Schroder, Edelstein and Keller 1989) and is in agreement with many other studies of these tasks (See Meehan 1984) It is therefor concluded that the phenomenon of displacement volume is gender biased and not recommended as a general task of cognitive measurement.

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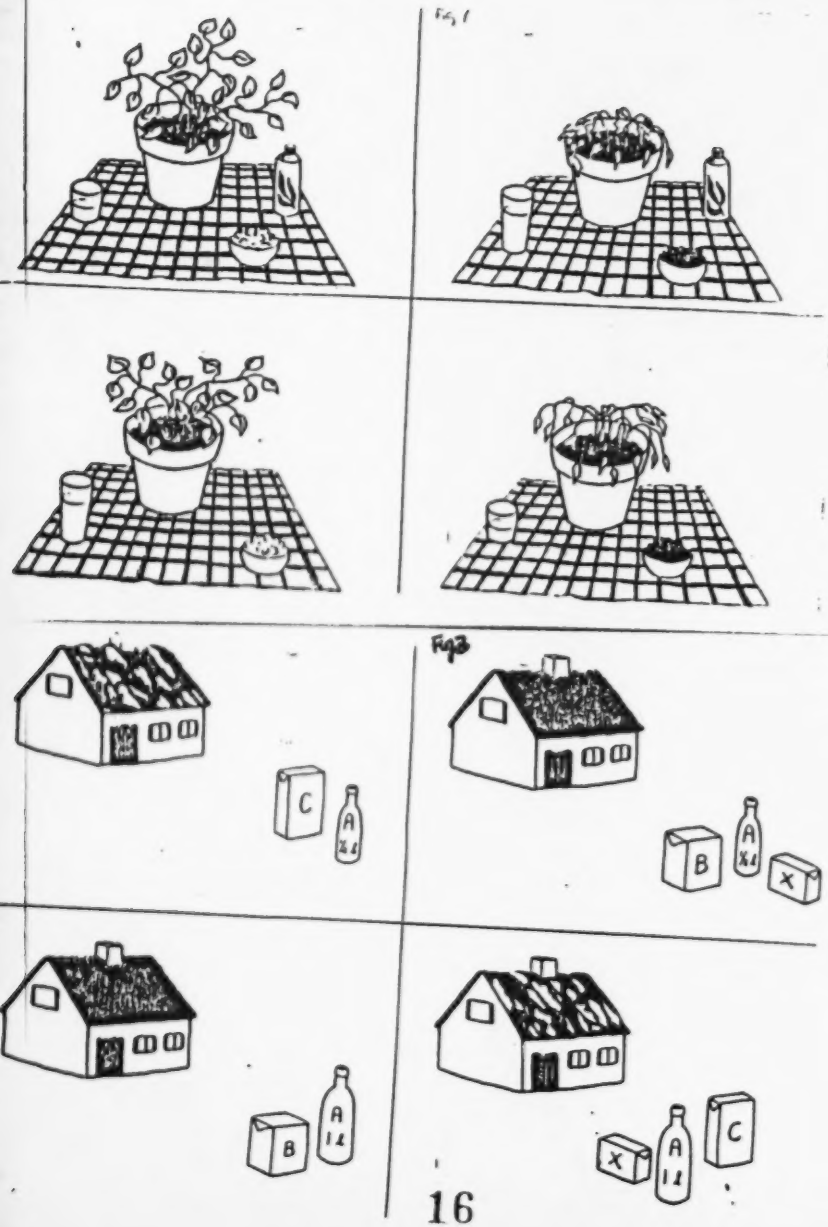
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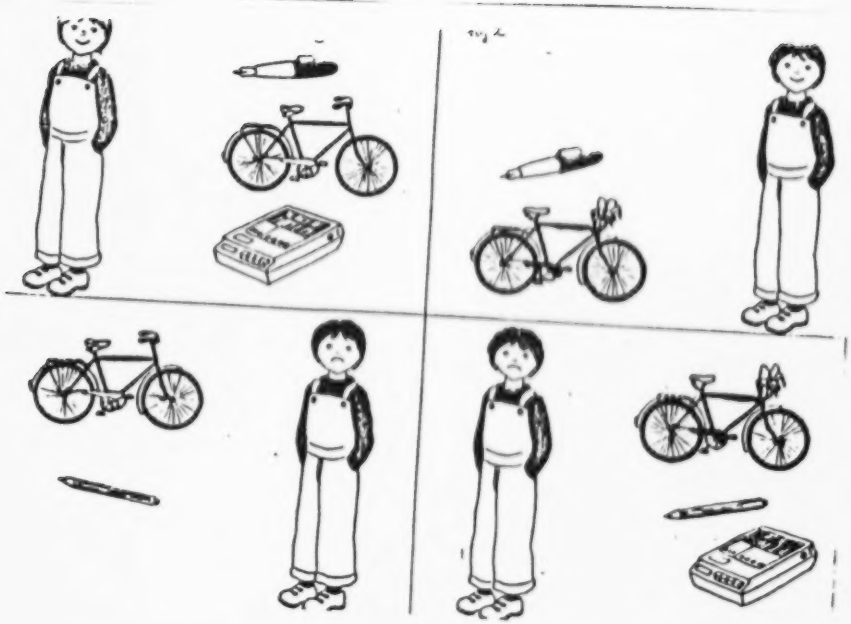
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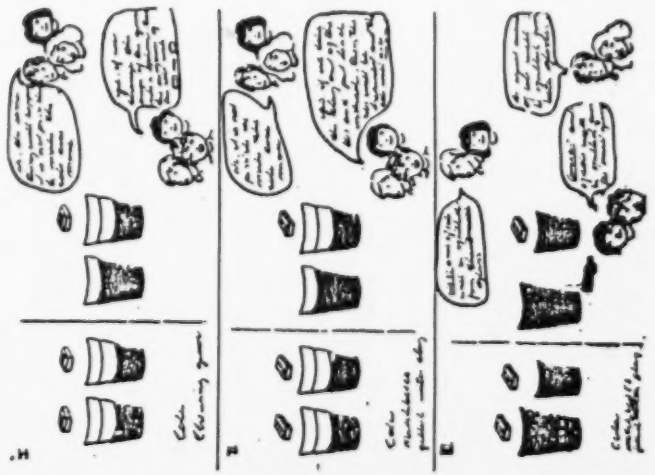
Fig 4

Role of Content . . .

Table 1: Piagetian stages of high and low ability 12-year-olds according to different tasks of variable isolation (%)

Task	Ability group	Concrete	Transitional	Formal
Pendulum	Low 1)	32	61	7
	High 2)	6	60	34
Plant	Low	50	43	7
	High	23	56	21
House	Low	32	59	9
	High	39	59	13
Toys	Low	64	27	9
	High	23	45	32

1) N=57 2) N=53

Table 2: Piagetian stages of high ability 12-year-olds by SES according to the pendulum task (%).

SES	N	Concrete	Transitional	Formal
Low	26	12	69	19
High	27	0	52	48

Table 3: Performance of high and low ability 12-year-olds on different content versions of the volume tasks.

		3 formal tasks		3 cartoon tasks		
Group / N	Ver.	MSD		M	SD	t
Low	Ans.	1.31	.83	1.49	.98	-1.43
(N=57)	Expl.	.88	.94	1.00	1.11	-2.74*
High	Ans.	2.22	.86	2.12	.95	1.0
(N=53)	Expl.	1.84	1.16	1.77	1.26	.3

*P<.005 1) Max. score is 3.0

Table 4 Performance of high ability 12-year-olds by gender on conservation of volume composite variables(N = 54, 28 M and 26 F)

Tasks/ var.	Gender	M	SD	t	m.d
Formal ans.	M	1.64	.82	1.05	
	F	1.45	.84		
Formal expl.	M	1.57	.74	2.30*	.83
	F	1.11	.71		
Cartoon expl.	M	1.67	.54	2.47**	.68
	F	1.26	.66		
Cartoon expl.	M	1.53	.79	2.40**	.65
	F	1.00	.84		
Shape ans.	M	1.75	.51	.35	
	F	1.69	.67		
Shape expl.	M	1.53	.74	1.68	
	F	1.15	.92		
Weight ans.	M	1.57	.83	2.18*	.61
	F	1.03	.95		
Weight expl.	M	1.57	.83	3.50**	.69
	F	96	93		
Size ans.	M	.64	.48	- .08	
	F	.65	.49		
Size expl.	M	.78	.41	2.89**	.78
	F	.42	.50		

1) Two tasks every time, max. score is 2.0.

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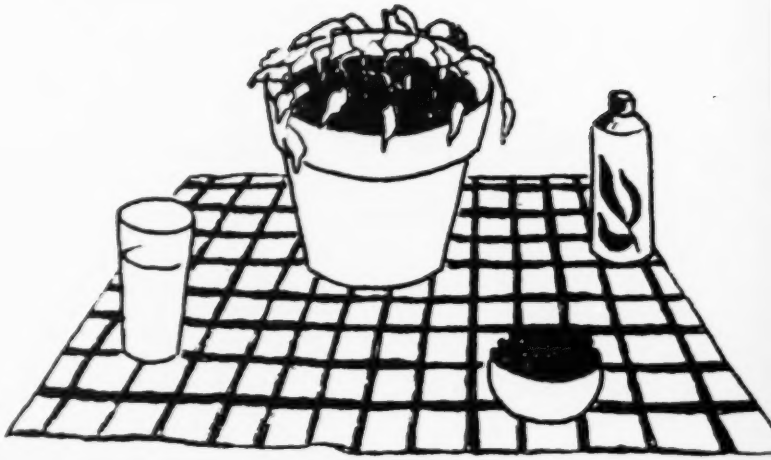
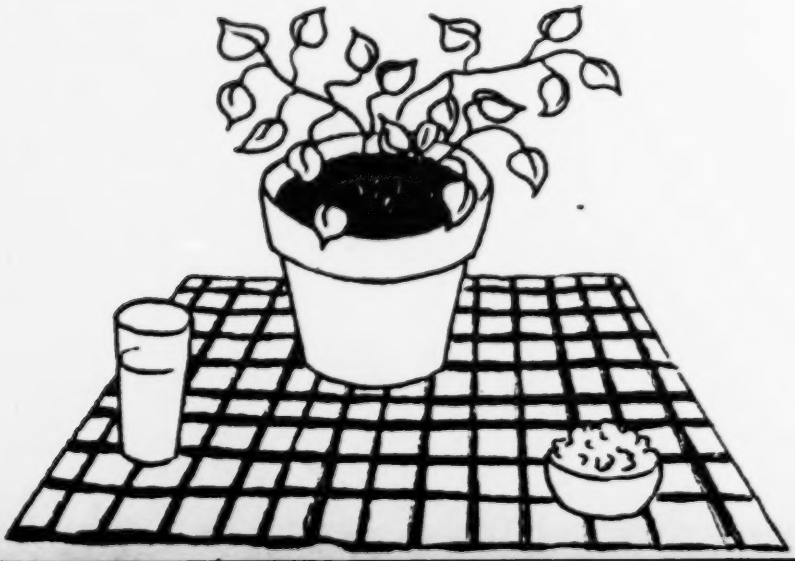
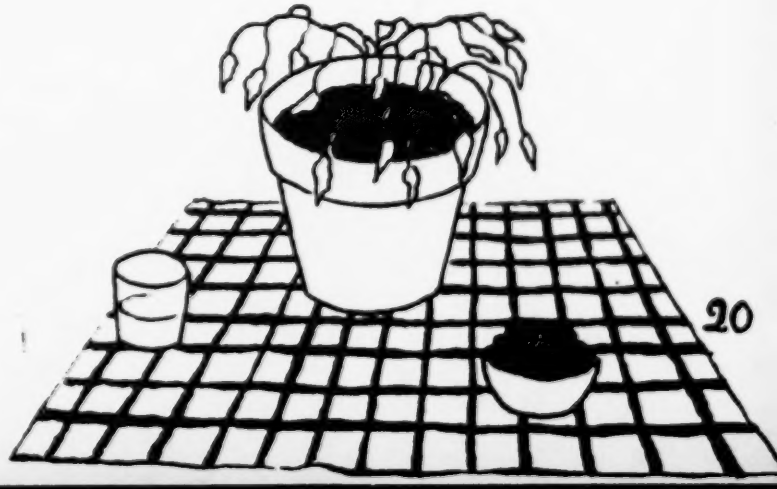
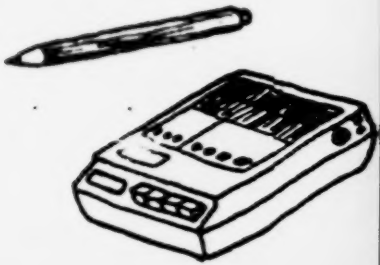
Fig 1









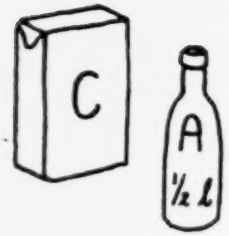
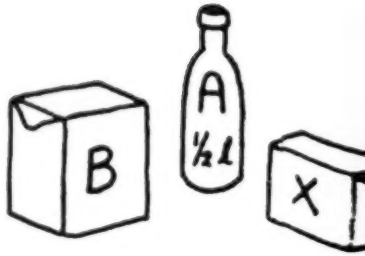


Fig 3



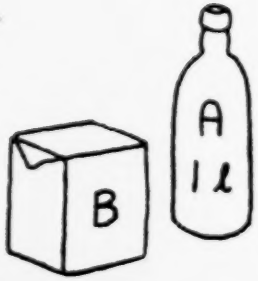


Fig 4

I

No, the same thing will happen it is not possible to make the cola rise more
yes, if we change the shape of the gum into a sphere, then the surface of the cola will
Cola
Chewing gum

II

No, it is not possible to make the cola rise more
yes, if we take the clay out of the box and put back instead, then the box will be heavier and the cola will rise more
Cola
Matchboxes
filled with clay

III

less amount of cola will be spilled from the small glass
An equal amount of cola will be spilled from both glasses
Cola
matchboxes
filled with clay

Table 1: Piagetian stages of high and low ability 12-year-olds according to different tasks of variable isolation (%)

Task	Ability group	Concrete	Transitional	Formal
Pendulum	Low 1)	32	61	7
	High 2)	6	60	34
Plant	Low	50	43	7
	High	23	56	21
House	Low	32	59	9
	High	28	59	13
Toys	Low	64	27	9
	High	23	45	32

1) N=57 2) N=53

Table 2: Piagetian stages of high ability 12-year-olds by SES according to the pendulum task (%).

SES	N	Concrete	Transitional	Formal
Low	26	12	69	19
High	27	0	52	48

Table 3: Performance of high and low ability 12-year-olds on different content versions of the volume tasks.

		3 formal tasks		3 cartoon tasks		
Group / N	Var.	M	SD	M	SD	t
Low (N=57)	Ans.	1.31	.83	1.49	.98	-1.43
	Expl.	.68	.94	1.00	1.11	-2.74*
High (N=53)	Ans.	2.22	.86	2.12	.95	1.0
	Expl.	1.84	1.16	1.77	1.26	.9

*P<.005

1) Max. score is 3.0

Table 9. Performance of high ability 12-year-olds by gender on conservation of volume composite variables(N = 54, 28 M and 26 F)

Tasks/ var.	Gender	M	SD	t	m.d
Formal ans.	M	1.64	.62	1.05	
	F	1.46	.64		
Formal expl.	M	1.57	.74	2.30*	.63
	F	1.11	.71		
Cartoon expl.	M	1.67	.54	2.47**	.68
	F	1.26	.66		
Cartoon expl.	M	1.53	.79	2.40**	.65
	F	1.00	.84		
Shape ans.	M	1.75	.51	.35	
	F	1.69	.67		
Shape expl.	M	1.53	.74	1.68	
	F	1.15	.92		
Weight ans.	M	1.57	.83	2.18*	.61
	F	1.03	.95		
Weight expl.	M	1.57	.83	2.50**	.69
	F	.96	.95		
Size ans.	M	.64	.48	- .08	
	F	.65	.48		
Size expl.	M	.78	.41	2.89**	.78
	F	.42	.50		

1) Two tasks every time, max. score is 2.0.